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EXECUTION AND ANALYSIS OF THERMAL ENERGY STORAGE SYSTEM USING PCM

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ABSTRACT

Thermal energy storage systems are at present experiencing unrest, vowing to their powerful contribution in current innovation, and their broad applications, for example, space warming, water warming, squander heat utilization, cooling and air conditioning. Sun controlled warm imperativeness storing contraptions need heavier research thought in light of sporadic and whimsical nature of daylight based essentialness which is exceptionally capable, preservationist and strong imperativeness resource. Among the different sorts of potential outcomes to store vitality frameworks utilizing distinctive materials, phase Change Materials (PCM) can be favored for their consistency in dormant warmth stockpiling. The utilization of PCM is a viable method for invisibility heat energy and has the upsides of having elevated stock pile depth and is isothermal in nature of the ability procedure.

In the present test work, thermal energy storage system (TESS) is structured, manufactured and commissioned to gather warm execution information on the thermal energy storage tank. This TES tank is having spherical capsules, inserted with phase change material as stearic acid. The heat transfer fluid (HTF) is utilized as water. The present work means to research the charging (dissolving of PCM) and discharging (hardening of PCM) characteristics of phase change material in TES tank.

KEYWORDS: Phase Change Material (PCM), Latent Heat Transfer Fluid (LHTF), Stearic Acid & Thermal Energy Storage (TES)

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Original Article

1. INTRODUCTION

Energy from the sun is comprehensively used in private cool/warm and DHW making systems. A standout amongst the most productive techniques to store warm vitality is Latent Heat Thermal Energy Storage (LHTES) through the mix of PCM, using the high values of latent heat [1]. LHTES may store up 5 to 14 times greater heat per unit volume than sensible storage resources, for example H_2O [2]. Moreover, these resources have less warm conductivities referencing colossal power thickness. The imperativeness set away can be improved in a predictable temperature which can adequately be used by TES tank. LHTES materials be supposed to demonstrate assured properties such as warm, physical, dynamic and manufactured.

Stearic Acid is promising materials since they abuse productive energy storage in an ideal temperature go for joining into private warming/cooling frameworks. With respect to plan of profitable thermal energy storage units, additional examination is needed to survey the physical marvels and effectively actualize PCM. So as to conquer low conductivity, different strategies have been proposed including the utilization of CuO and Al_2O_3 nano-particles or the utilization of fins to expand exchange of heat [3, 4].

There are numerous phase change materials in the market and the determination of the fitting PCM which is to be utilized in a specific application must contemplate different specialized and material properties issues. A portion of these problems are, melting temperature which ought to satisfy the application region necessities, latent heat, chemical stability and thermal conductivity. These frameworks have numerous favorable circumstances like large heat storage limit in a unit volume and their isothermal conduct amid the charge and release procedures. These frameworks are not in business utilize like sensible heat storage (SHS) frameworks in light of the reduced heat exchange rate amid the charge and release procedures and high starting expense. A portion of the significant commitments toward this path are examined in the spin-off.

Few analysts [1, 5, 13, and 18]detailed numerical and trial examinations about liquefying and hardening attributes of various PCMs utilized in the TES framework. Sayigh [2] examined the warm presentation qualities of a solar tube collector (STC) framework with phase change energy storage diagnostically and tentatively. STC execution amid charging is considered and it is reasoned that balance structures are unequivocally influencing the softening procedure. Assis et al. [3] detailed exploratory investigation of softening in a circular shell. The outcomes demonstrated the impact of warm and geometrical parameters on liquefying/solidifying forms. Banaszek et al. [4] researched tentatively the strong fluid phase change in a winding thermal energy storage unit amid charging and discharging procedures. El Qarnia [6] played out a mathematical investigation to foresee the thermal conduct and execution of a solar based dormant heat storage unit utilizing different PCMs for warming the water. The quantity of cylinders, stream rate of water, mass of the PCM and so on. Were improved for giving summer climatic states of Marrakech city. Esenetal.[7] done a hypothetical examination to explore the presentation of a LHS unit combined with a sun based water warming framework utilizing diverse PCMs. Felix Regin et al. [8] built up a mathematical model for examining the conduct of a pressed bed containing circular cases loaded up with paraffin wax as PCM. Halawa et al. [9] exhibited a mathematical investigation of a PCM warm capacity framework with changing divider temperature. This paper talked about the average trademark so the dissolving/solidifying of PCMs labs in an air stream and displayed a few aftereffects of the numerical reproduction as far as air outlet temperatures and warmth exchange rates amid the entire times of liquefying and solidifying. Ismail and Henrıquez [10] revealed the aftereffects of mathematical and test examinations on LHS by differing parameters like heat transfer fluid (HTF) delta temperature, HTF stream rate, and material of the PCM container. In this LHS framework water was utilized as PCM and the heat exchange process amid charging and releasing procedures was mimicked. Jian-you [11] detailed a mathematical and trial examination for heat transfer in a triplex concentric cylinder with PCM for a thermal energy storage framework. The connection between the strong and fluid periods of PCM versus time and hub position, and the time-wise variety of vitality put away/discharged by the framework were introduced and talked about. Mehling et al. [12] inferred that putting PCM modules at the highest point of the water tank in TES has given greater capacity thickness and repaid the warmth misfortune at the top surface by doing both mathematical and test examination. Nallusamy and Velraj [14] examined both hypothetically and tentatively the presentation of a joined reasonable and inert thermal energy storage unit coordinated with a solar powered water warming framework. In this paper, the immediate warmth put away, total warmth put away, and charging rate is considered in detail. Seeniraj and Narasimhan [15] did mathematical examinations to enhance the presentation of a TES framework by utilizing different PCMs and fins. Sharma et al. [16] detailed hypothetical examination on warmth move wonders in a LHS framework utilizing diverse warmth exchanger materials and distinctive PCMs (unsaturated fats). It is additionally detailed that capric corrosive has great similarity in the LHS framework contrasted with lauric corrosive, myristic corrosive, palmitic corrosive, and stearic corrosive. Shiina and Inagaki [17]

announced a method improving the warm conductivity of PCM utilizing immersed permeable metals by means of stage change materials. Results infer that the softening time of PCM is decreased impressively with low-conductivity PCMs and high-heat-exchange coefficient permeable metals.

(a) Copper Oxide **(b) Aluminum Oxide**

Figure 1: CuO and Al_2O_3 Nanoparticles

2. EXPERIMENTAL METHOD

The charging of TES is examined utilizing 2lit/min, 4lit/min, and 6lit/min stream rates through fluctuating inlet HTF temperatures. Likewise group astute releasing of TES is considered with various release stream rates, i. e., 2lit/min, 4lit/min and 6lit/min, by keeping the consistent inlet cold water i. e., 2lit/min at 30°C. At first the energy is put away within the capsule as reasonable warmth until the PCM achieves its liquefying temperature. As the charging procedure continues, energy storage is accomplished by dissolving the PCM at a steady temperature. At long last, the PCM turns out to be overly warmed. The energy is then put away as reasonable warmth in fluid PCM. Temperatures of the PCM and HTF are noted at an interim of 15min. The charging process is preceded until the PCM temperature achieves the estimation of 70°C.

The releasing procedure (energy recovery) tests are completed in a batch wise method. A specific amount of high temp water (40lits in light of the fact that a normal of one individual needs 20lit for scrubbing down) is pulled back from the TES tank for straight use and the tank is another time loaded up with cold water of amount equivalent to the measure of water pulled back. Once more, after a period interim of 15 min permitting the exchange of vitality from the PCM, another 20lit of water is pulled back from the TES tank. This procedure is preceded until the PCM temperature achieves 34°C.

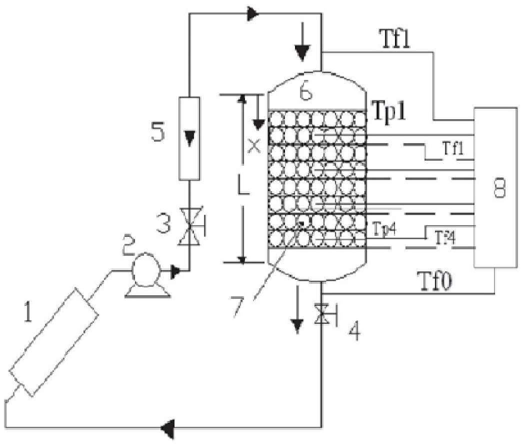


Figure 2: Schematic Outline of the Experimental Setup

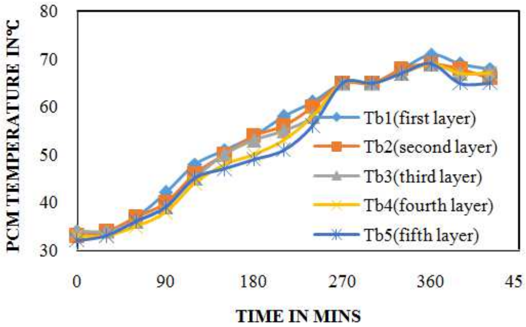
Figure 3: Photographic view of the Experimental Setup

1. Solar flat plate collector; 2. Pump; 3 & 4. Flow control valves; 5. Flow meter; 6. TES tank; 7. PCM capsules; 8. Temperature indicator, Tp & Tf: temperature sensors (RTDs)

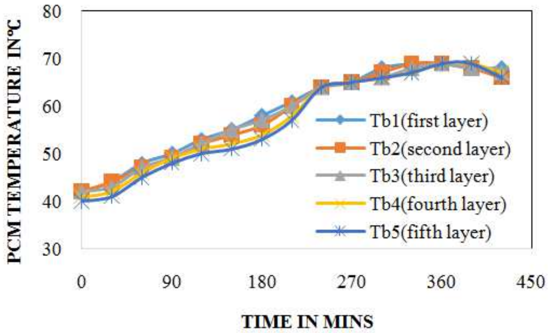
3. RESULTS AND DISCUSSIONS

The base liquid 40 liters of water was warmed up to 70^{0}C by sunlight based warmer, the base liquid water is blended to get the uniform temperature in the tank. The high temp water is circled into the storage tank with the assistance of a centrifugal p[ump. The heated water streams over the circular balls, these are put on a work, complete test comprises of 5 layers isolated by work, and each layer comprises of 16 balls. The circular balls are immersed in high temp water. A few tests are directed at the diverse stream rates of HTF, for example, 2, 4 and 6lit/min.

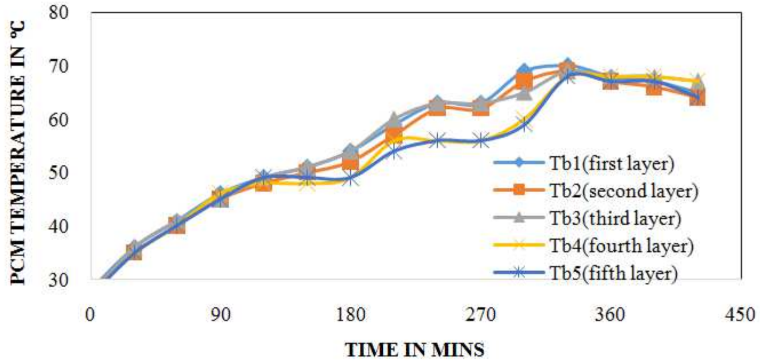
Amid the charging procedure, the heat exchange fluid 40 liters of water is put away in the thermal energy storage tank, and inlet and outlet stream rates stay steady while HTF will flow. Toward the starting the PCM temperature was 34^{0}C and stearic corrosive softening temperature was 59^{0}C. The heat energy is exchanged from the HTF to the round cases containing stearic acid to dissolve. Right off the bat the warmth is put away in the circular container then it is begun to achieve the stearic acid that goes to the 68^{0}C in light of the fact that to achieve the relentless temperature. In TES tank vitality put away in the dissolving type of the PCM at a specific temperature. PCM will be superheated at a steady temperature in the charging procedure. The reasonable warmth vitality put away as fluid PCM. The varieties of PCM temperatures and HTF temperatures are recorded with the interim of 15mins. The charging procedure is done till the PCM temperature compasses to the around 70^{0}C.



(a) Charging Process with Flow Rate 6lit/min (Base fluid)



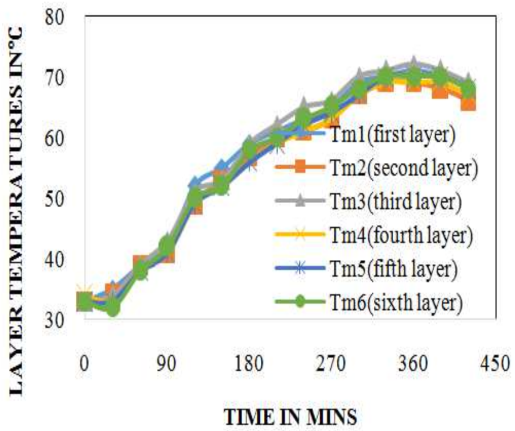
(b) Charging Process with Flow Rate 6lit/min (Base fluid+CuO)



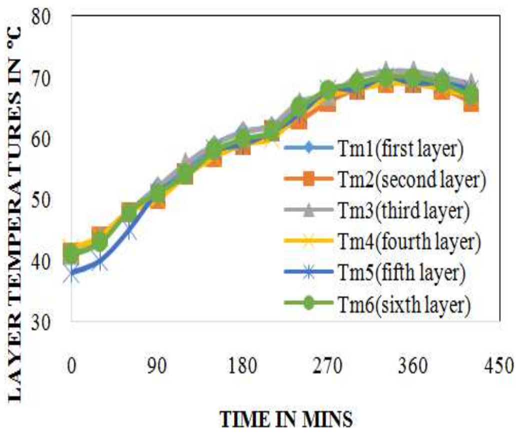
(c) Charging Process with Glow Rate 6lit/min (Base Fluid+Al_2O_3)

Figure 4: Charging Process in Different Flow Rates for Ball Temperatures

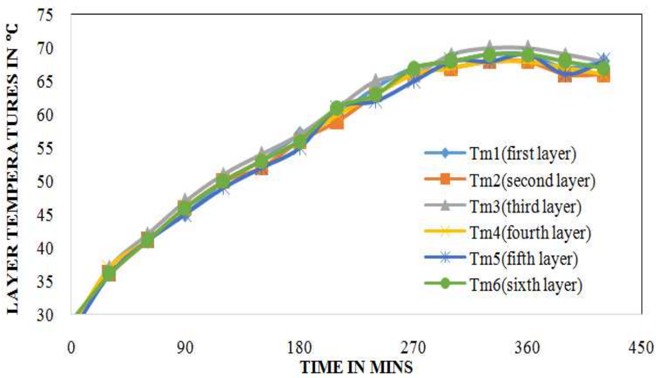
Figure 4 represent the variation between charging time and the PCM temperatures for mass flow rate 6lit/min of HTF when circulated from variable heat source, with stearic acid is used as PCM, CuO and Al_2O_3 as nano particles. From the figure it may be observed that PCM temperature increases quickly till the phase change temperature is attained and remain constant during phase change and afterward temperature of liquid PCM increases gradually and possess heat transfer fluid temperature (HTF).



(a) Charging Process with 6lit/min (Base fluid)



(b) Charging Process with 6lit/min (Base fluid+CuO)



(c) Charging Process with 6lit/min (Basefluid+Al_2O_3)

Figure 5: Charging Process in different Flow Rates for Layer Temperatures

Figure 5 represents the relation between the charging time and layer temperatures with flow rate 6lit/min and using stearic acid as a PCM. From the figure it may be observed that first layer temperatures are high when compared with the remaining layer temperatures. From figure it may be observed that charging time is less for figure 4b when compared with the remaining figures.

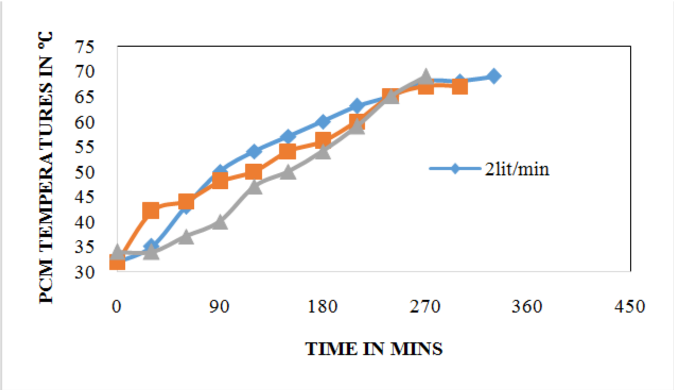


Figure 6: Charging Process with Basefluid

Figure 6 represent the variation between charging time and the PCM temperatures for mass flow rates 2, 4 and 6lit/min of HTF while dispersed from variable heat energy source, with stearic acid is used as PCM and charging time for mass flow rate 2lit/min is 345 mins. Charging time for mass flow rate 4lit/min is 315 mins. Charging time for mass flow rate 6lit/min is 300 mins.

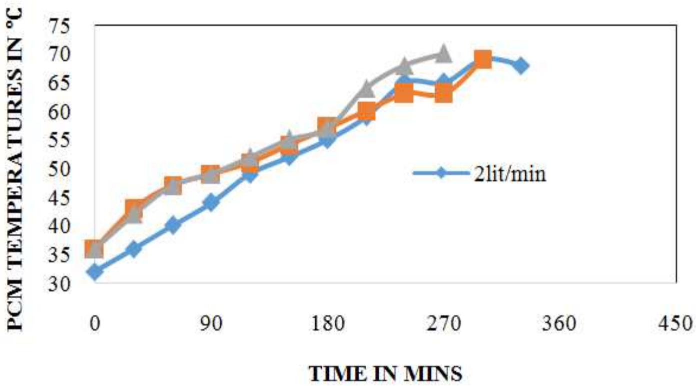


Figure 7: Charging Process with Basefluid+CuO

Figure 7 represent the variation between charging time and the PCM temperatures for mass flow rates 2, 4 and 6lit/min of HTF while dispersed from variable heat energy source, with stearic acid is used as PCM and CuO as nano particles. Charging time for mass flow rate 2lit/min is 315 mins. Charging time for mass flow rate 4lit/min is 285 mins. Charging time for mass flow rate 6lit/min is 270 mins.

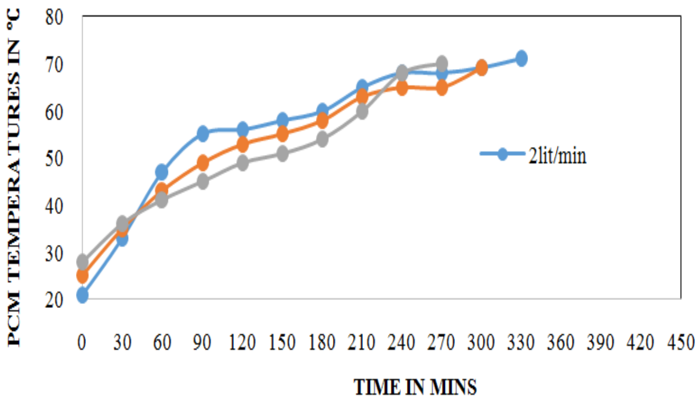


Figure 8: Charging Process with Basefluid+Al2O3

Figure 8 represent the variation between charging time and the PCM temperatures for mass flow rates 2, 4 and 6lit/min of HTF while dispersed from variable heat energy source, with stearic acid is used as PCM and Al2O3 as nano particles. Charging time for mass flow rate 2lit/min is 330 mins. Charging time for mass flow rate 4lit/min is 300 mins. Charging time for mass flow rate 6lit/min is 285 mins.

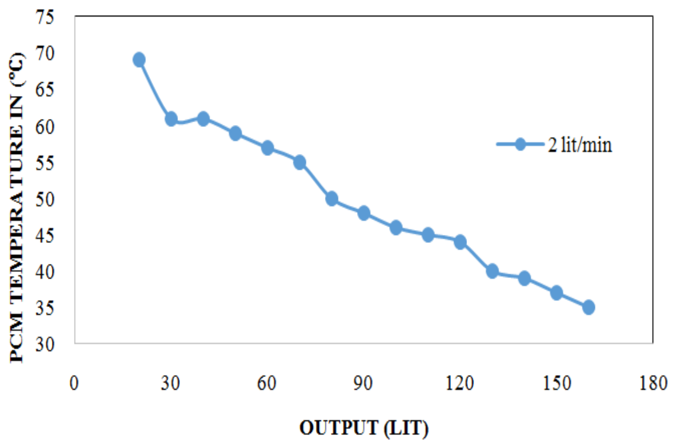


Figure 9: Discharging Process with Flow Rate 2lit/min

From the figure 9 it may be noted that 160 liters of hot water collected from the TES tank by using stearic acid as PCM with mass floe rate 2lit/min and the figure showing that the PCM temperature is decreasing linearly.

4. CONCLUSIONS

In the charging procedure utilizes a changing heat energy source (sun oriented) the outcomes demonstrate that the distinctive stream rates (2, 4, and 6lit/min) of HTF does not affect the charging time. Since the span for charging is approximately 9hrs (i. e.8:00 a. m to 5:00 p. m.), which is along length, the heat exchange rate as of HTF to PCM has a low impact (5– 10%). For the releasing procedure there is a small distinction in the amount of warm vitality recouped in the group shrewd release method for various stream rates(2, 4 and6lit/min) despite the fact that the amounts of high temp water released are unique. This is on the grounds that in the 6lit/min release stream rate the normal temperature is high and the amount is low, and on account of 2lit/min release stream rate the normal temperature is low and the amount is all the additional likewise.

The figures 4 and 5 demonstrate the accusing procedure of regard to time with the stream rates of 2, 4 and 6litres/min with water, nano molecule (Al_2O & CuO) speaks to the most extreme stream rate of HTF for PCM temperature stream and Layer Temperature charging process.

The figure 5, 6 and 7 demonstrates the accusing procedure of regard to time with the stream rates of 2,4 and 6litres/min with water, nano particle(Al_2O_3 & CuO) speaks to the greatest stream rate of HTF for PCM temperature stream charging process.

The figure 8represents the releasing procedure regarding time with the stream rates of 2Liters/min for the examination concerning charging process utilizing Stearic Acid and nano molecule (Al_2O_3&CuO).

With this test we can demonstrate that the Charging Process with PCM is higher HTF than Discharging Process @ 80% TESS.

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